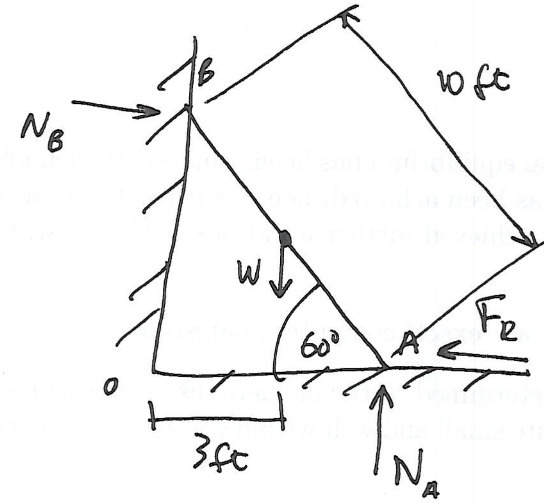
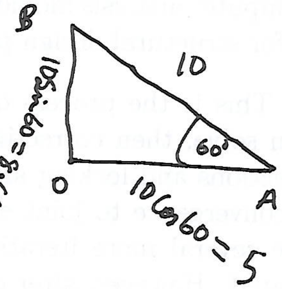
8 - 6

Free body diagram





$\Sigma F_y = 0$

$W - N_A = 0$

$N_A = W = 180 \text{ lb.}$

$\Sigma M_B = 0$

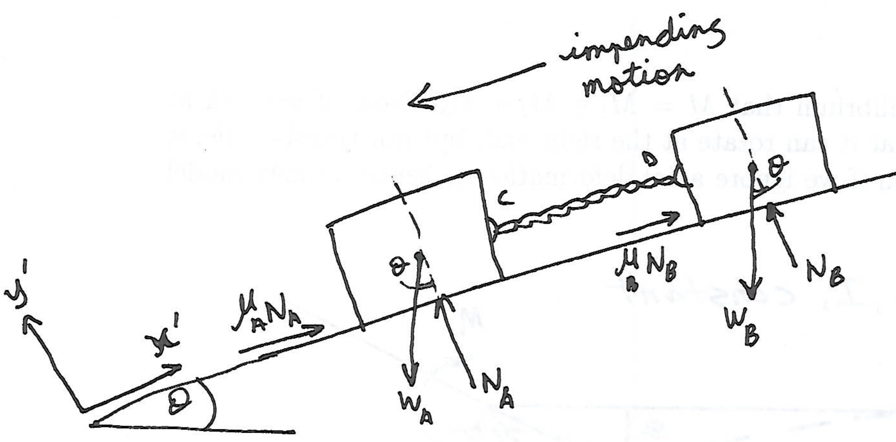
$-3W + 5N_A - 8.66 F_R = 0$

$F_R = \dfrac{-3(180) + 5(180)}{8.66} = 41.57 \text{ lb}$

but $F_R = \mu_s N_A$

$\mu_s = \dfrac{41.57}{180} = 0.2309$

8-21



So because μ_A and μ_B are not the same and also W_A and W_B are not the same, the crates will begin sliding under different conditions.

Also connector CD is a cable, so A may be able to pull B with it but B cannot push A with it, unless CD was some solid connector.

So lets find which one on its own will slide first.

A:
$$\sum F_{y'} = 0$$

$$W_A \cos\theta = N_A \Rightarrow N_A = 200\cos\theta \quad \text{— (1)}$$

$$\sum F_{x'} = 0$$

$$W_A \sin\theta = \mu_A N_A \Rightarrow N_A = \frac{200}{0.25}\sin\theta \quad \text{— (2)}$$

$(2)/(1)$:

$$\frac{\frac{200}{0.25}\sin\theta}{200\cos\theta} = 1$$

$$\Rightarrow \tan\theta = 0.25$$

$$\theta_A = 14.03^\circ$$

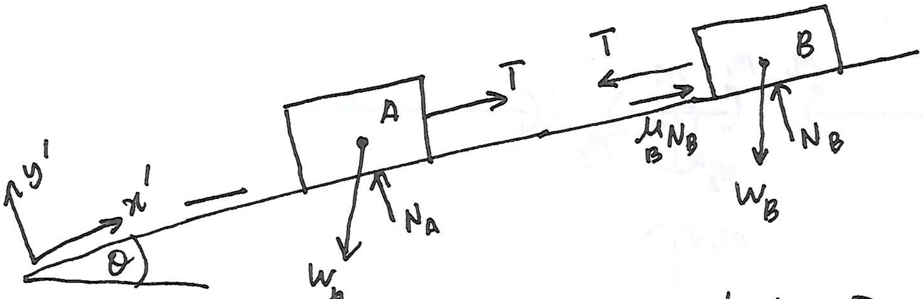
B : likewise

$$\frac{\frac{150}{0.35}\sin\theta}{150\cos\theta} = 1$$

$$\tan\theta = 0.35$$

$$\theta_B = 19.29^\circ$$

So crate A will slide first, pull on the cable and subsequently B will begin sliding. So when the full tension is mobilized in cable and B begins to slide



Applying Equilibrium conditions to crate B, first.

$$\Sigma F_{y'} = 0$$

$$W_B \cos\theta = N_B \quad \text{—— (1)}$$

$$\Sigma F_{x'} = 0$$

$$-T - W_B \sin\theta + \mu_B N_B = 0 \quad \text{—— (2)}$$

(1) in (2)

$$T + W_B \sin\theta = \mu_B W_B \cos\theta \quad \text{—— (3)}$$

Now analysing crate A at same instant

$\Sigma F_{y'}$; $\quad W_A \cos\theta = N_A \quad$ —— (4)

$\Sigma F_{x'}$; $\quad T - W_A \sin\theta + \mu_A N_A = 0 \quad$ —— (5)

OR: we can set up system of 4 equations, 4 unknowns (call $\cos\theta = X$, $\sin\theta = Y$)

(4) in (5)

$$T - W_A \sin\theta = -\mu_A W_A \cos\theta \quad \text{—— (6)}$$

(3) − (6) ;

$$W_B \sin\theta + W_A \sin\theta = \mu_B W_B \cos\theta + \mu_A W_A \cos\theta$$

$$\sin\theta \left(W_B + W_A \right) = \cos\theta \left(\mu_B W_B + \mu_A W_A \right)$$

$$\tan\theta = \frac{\mu_B W_B + \mu_A W_A}{W_B + W_A} = \frac{0.35(150) + 0.25(200)}{200 + 150}$$

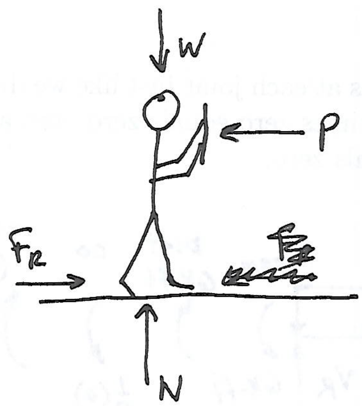
$$\theta = 16.32^\circ$$

From (6)

$$T = 200 \sin 16.32 - 0.25(200) \cos 16.32$$

$$= 8.21 \text{ lb}$$

8-27



At impending slippage P is a reaction force on the man from the fridge because the man is exerting a force on the fridge.

$\sum F_y = 0$

$$N - W = 0 \Rightarrow N = W = 150 \text{ lb.}$$

$\sum F_x = 0$

$$P - F_R = 0 \Rightarrow P = F_R$$

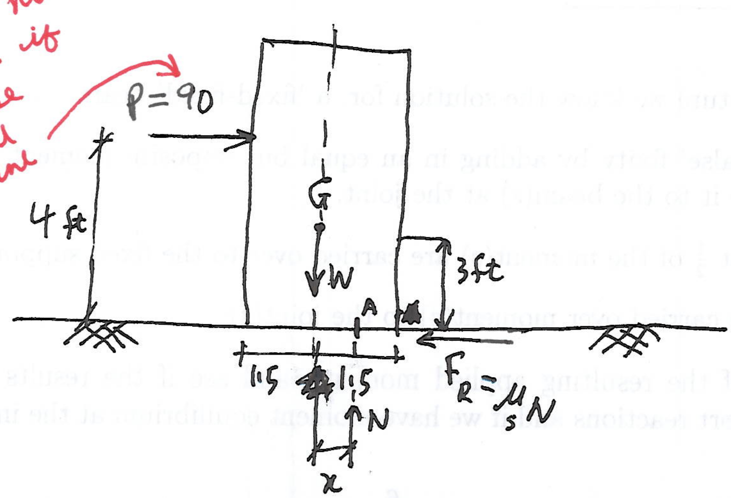
$$P = \mu_s N = 0.6(150) = 90 \text{ lb}$$

This is the max possible from man.

Pay attention!

So by 'action and reaction' (Newton's 3rd Law) P is the (max) force exerted by the man on the fridge.

Note that we are not sure at this stage if max P = 90 will be needed, so we shall check at some point



$\Sigma F_y = 0$

$N - W = 0$

$N = W = 180 \text{ lb}$

so that F_R on fridge,

$F_R = 0.25(180) = 45 \text{ lb}.$

OR ;

$\Sigma F_x = 0$

so

$P = F_R$

$90 = 0.25 N$

$N = 360 \text{ lb}$ OK, so does not match, so we have an issue. without external help N cannot exceed W, so use $F_R = 45$ lb, and $N = 180$ lb

Caution : Pay Attention here !!

Now $P = 90 \text{ lb} > F_R = 45 \text{ lb}$

1. so fridge will ~~[illegible]~~ move because the man's force will overcome the frictional resistance.

3. So the question is will the fridge slide or tip over?

4. To tip over the normal force must act at A, ($x = 1.5$ ft), otherwise it will slide.

2. Also the man can have up to 90 lb reaction force on him without slipping, so yes he can move the fridge.

So if we use $F_R = 45$ lb, then for equilibrium for the fridge

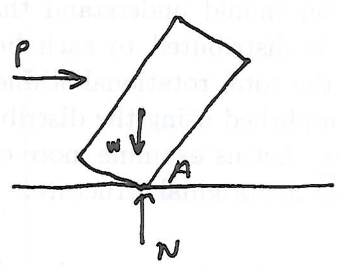
$$\sum F_x = 0 \Rightarrow P' = F_R = 45 \text{ lb.}$$

Now lets take moments about A,

$$\sum M_A = 0 \;;\; -P'(4) + Wx = 0$$

$$= 0$$

if $x = 1.5$, then the fridge is tipping over.



Note that A is a 'sliding' location for where the normal reaction acts on base of fridge

so $$-45(4) + 180x = 0$$

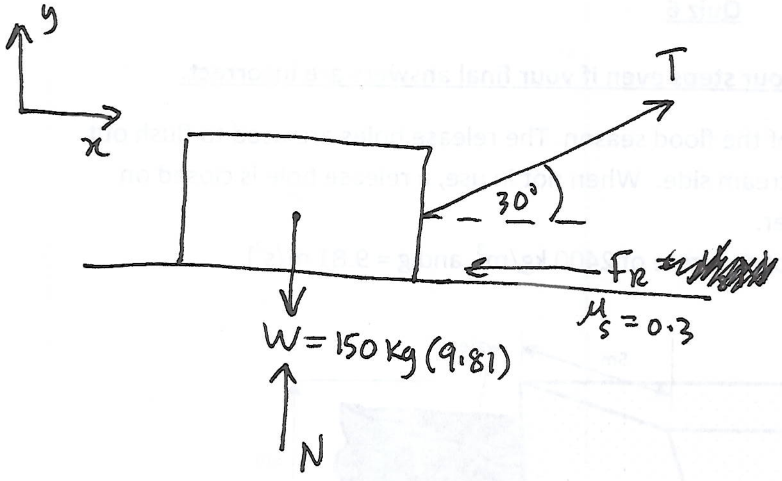
(using my calculator solve function)

$$x = 1.00 \text{ ft} \neq 1.5 \text{ ft}$$

so fridge does not tip over but slides!

A good way to check your answer is the x value. If $x > \text{base}/2$ then we have an error somewhere. It will always be between 0 and $\text{base}/2$. If not, you may have inserted the wrong N or F_R. Eg if we used $P = F_R = 90$ lb, we would get $x = 2$ ft, which is not physically possible for this fridge.

8-43



$$\sum F_y = 0$$

$$N - W + T\sin 30 = 0$$

$$N = W - T\sin 30 \quad \text{— (1)}$$ This is the normal force.

$$\sum F_x = 0$$

$$T\cos 30 - F_R = 0$$

$$F_R = T\cos 30 \quad \text{— (2)}$$

we also know that

$$F_R = \mu_s N = 0.3(W - T\sin 30)$$

so

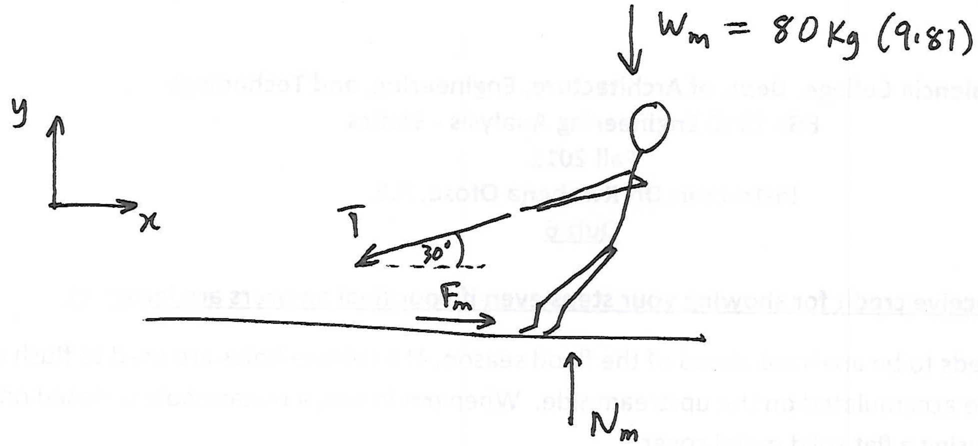
$$T\cos 30 = 0.3(W - T\sin 30) \quad \text{— (3)}$$

solve for T

$$T \cos 30 = 0.3\left(150(9.81) - T \sin 30\right)$$

using my calculator solve button

$$T = 434.48 \text{ N}$$



$$\sum F_x = 0$$

$$F_m - T\cos 30 = 0$$

$$F_m = T\cos 30 \quad \text{— (4)}$$

$$\sum F_y = 0$$

$$-T\sin 30 - W_m + N_m = 0$$

$$N_m = T\sin 30 + W_m \quad \text{— (5)}$$

so

$$F_m = \mu N_m = \mu\left(T\sin 30 + W_m\right) = T\cos 30 \quad \text{— (6)}$$

OR :

(6) = (3)

$$0.3\left(W - T\sin 30\right) = \mu\left(T\sin 30 + W_m\right)$$

from (6) solve for μ.

$$\mu\left[434.48 \sin 30 + 80(9.81)\right] = 434.48 \cos 30$$

using my solve button on calculator

$$\mu = 0.376$$

comments:

In this problem the normal force was the weight plus the vertical component of the applied tensile force. For the crate this ~~added~~ subtracted from the weight yielding a lower normal force and hence less friction between the crate and the surface. For the man the opposite happened.

Always consider the above when determining the normal force.

In some cases you may have the above occurring on an inclined plane. Find a problem with that set up to test your understanding of the concepts.